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Carbon Monoxide Study, Spokane, Washington November 21-December 19, 1980

(U.S.) Environmental Protection Agency
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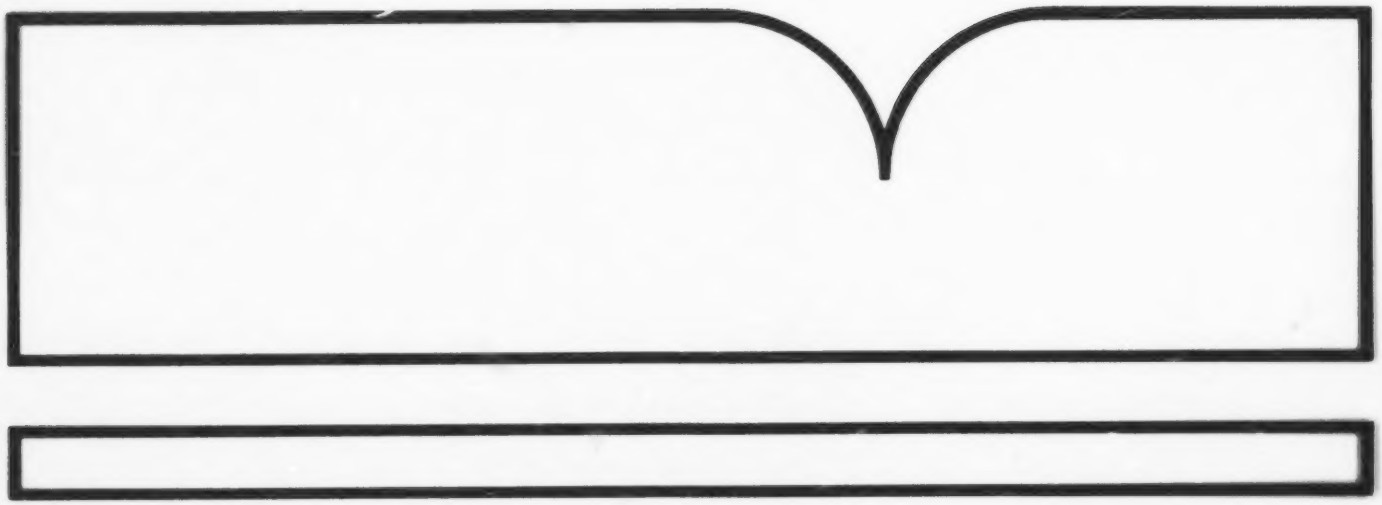

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February 1981

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Carbon Monoxide Study

Spokane, Washington
November 21-December 19, 1980

Executive Summary

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CARBON MONOXIDE STUDY

SPOKANE, WASHINGTON

EXECUTIVE SUMMARY

NOVEMBER 21 - DECEMBER 19, 1980

PREPARED BY

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SURVEILLANCE AND ANALYSIS DIVISION

FOR

AIR PROGRAMS BRANCH

AIR AND HAZARDOUS MATERIALS DIVISION

U.S. ENVIRONMENTAL PROTECTION AGENCY

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PREFACE

Under the Clean Air Act of 1970, the U.S. Environmental Protection Agency has established standards for carbon monoxide in air external to buildings to which the public has access. In a number of cities, including Spokane, these standards have not yet been attained. Plans to achieve the standards are required under the Clean Air Act Amendments of 1977 (PL 95-95). It is hoped that the material presented in this report will assist in formulating and evaluating such plans for achieving attainment of the standards.

ABSTRACT

An ambient air sampling program was designed and implemented to obtain information relative to the magnitude and spatial distribution of carbon monoxide levels in Spokane's central business district. Integrated bag samples were collected from a 16 site study network during 20 weekdays spanning November and December of 1980. Samples from each site were analyzed by the non-dispersive infrared method to yield a daily 8-hour average concentration for comparison with values reported by the four permanent monitors sited in the study area. Sampling and analytical protocols were developed in concert with rigorous quality control provisions to ensure the collection of valid, comparable data.

Using an array of linear regression formulas arising from analysis of the study data, the permanent monitoring network effectively characterized carbon monoxide concentrations at all study sites. The permanent monitoring network also adequately represented the maximum carbon monoxide concentration reported from the study network, compared without respect to day of occurrence. However, the permanent monitoring network was less successful in representing the daily maximum, and on occasion, exhibited sub-exceedance values when a study site elsewhere in the study area reported an exceedance of the 9.0 ppm 8-hour standard.

On balance, the study results indicate that the carbon monoxide problem is areawide in the study portion of downtown Spokane, and is primarily the result of highly localized contributory factors. Further, the study established the potential efficacy of using data generated by the existing permanent monitoring network to characterize carbon monoxide levels at other locations in the central business district.

ACKNOWLEDGEMENTS

I gratefully acknowledge the assistance of members of the Washington State Department of Ecology and the City of Spokane. With their cooperation and special efforts, difficult obstacles to the implementation of this study were either surmounted or wholly avoided. Finally, I wish to express my gratitude to many members of EPA Region 10's staff, especially those of the Surveillance & Analysis Division for their guidance and assistance.

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INTRODUCTION

Since 1968, when routine ambient monitoring began in Spokane's Central Business District (CBD), violations of the 8-hour National Ambient Air Quality Standard (NAAQS) for carbon monoxide* (CO) have been recorded at several sites operated by the Washington State Department of Ecology. However, additional information concerning the severity and spatial distribution of the CO problem in Spokane's CBD was sought to assist in evaluating the relationship between permanent monitors and CO concentrations elsewhere in the CBD. A study was conceived and conducted to address these needs. This report presents the major results and conclusions derived from the study.

While several methods exist by which to compare data from the study sites and the permanent monitors, two basic approaches are presented in this report to examine the representativeness of the permanent monitors.

The first approach compares data on a day-by-day basis (Type 1 approach). Because the study sites were sampled during just one 8-hour period (10:00 a.m. to 6:00 p.m.) each day, data from the permanent monitors for the identical period were chosen for purposes of temporal congruity, permitting comparisons of relative concentrations throughout the study area. Data from the permanent monitors for other

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*Established by EPA as 9 ppm and not to be exceeded more than once per year.

periods outside the daily study interval are available for additional analyses of variability during a day. These analyses will not be attempted at this time.

The second approach (Type 2) compares data from the entire 20-day study, regardless of whether the compared data share the same day of occurrence. This method of analysis lends itself towards examining patterns and frequencies of concentrations throughout the study area. Data for the designated study period (10:00 a.m. to 6:00 p.m.) from study sites and permanent monitors were compared using this approach.

The study results that follow are distillations of the most significant results and conclusions stemming from a second and more extensive treatment. Because of time constraints, a second more detailed report will not be performed now. All data pertinent to the sampling and quality assurance aspects of the study will be available from EPA's Regional office in Seattle. The state monitoring data may be obtained from the Washington State Department of Ecology (DOE) in Olympia, Washington. It should be noted here that all DOE monitoring data are unvalidated and incomplete at this writing and are subject to further editing, although only minor changes are anticipated. Meteorological data originating at Spokane International Airport were accessed from the National Weather Service. This source of data is some distance from the CBD and the relationship of meteorology at the airport with that in the CBD is not well known.

Meteorological data more proximate to the study area were being collected at sites operated by the Washington State Department of Transportation, but are unavailable at this time. Finally, traffic counters were not operated at the temporary monitoring sites, except in those random instances where an EPA site happened to coincide with a short-term traffic count survey operated by the city as part of its routine program.

The reader's attention is called to the following qualifications borne by the study results:

1) The study was conducted following the city's implementation of a limited parking ban (see Figure 1) aimed at reducing congestion on the major legs (Washington, Stevens, Lincoln, and Monroe Streets) carrying traffic through the CBD. The effect this parking ban has on traffic dynamics and CO levels in these legs, and streets interior to them, is not known. This situation encumbers comparisons of this data with data generated under some other condition.

2) Due to the nature of the sampling effort and the report deadline, only data generated in the study period (10:00 a.m. to 6:00 p.m.) were considered for correlative analysis. Just as the inter-site relationships may exhibit some degree of daily variability, these relationships may also vary during periods within a day for which comparable study data are unavailable. This report makes no attempts to quantify this variability, but relies solely on the merit of relativistic analyses from which to make statements on the significance of study results.

City of Spokane
On-Street Parking Prohibitions
Implemented September, 1980

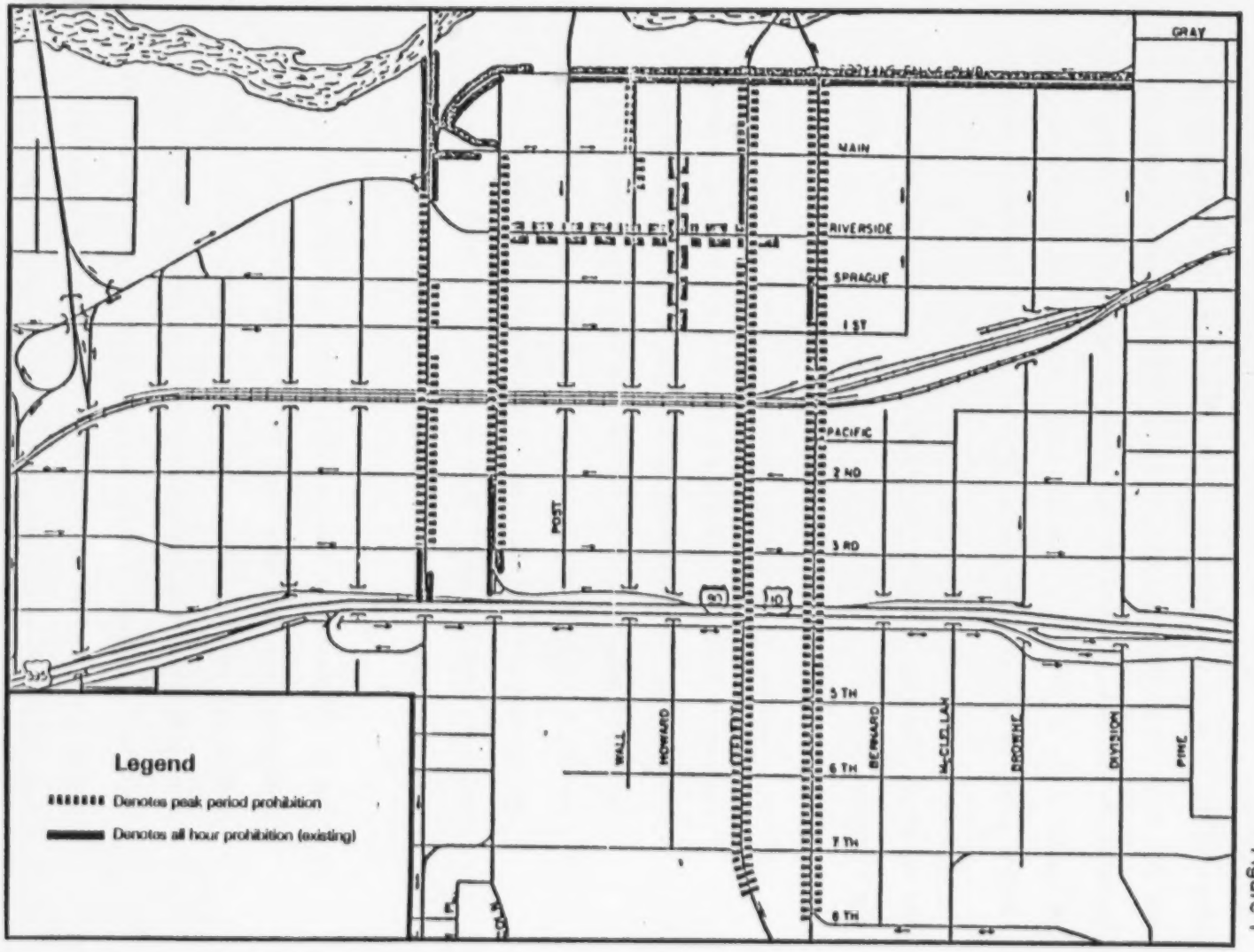

Figure 1

3) Due to the nature of the sampling methodology, some uncertainties about the absolute veracity of the data have been recognized and accepted by us from the study's inception. Intensive measures were taken to ensure the collection of data having both high and demonstrable quality. Correlative analysis of data returned by collocated study sites and permanent monitors indicate excellent agreement. In light of these results and because rigorous quality control functions were applied uniformly throughout the entire study network, we are reasonably assured that the network produced data of acceptable precision, accuracy, and comparability.

4) There are limitations an abbreviated (20-day) study can impose on interpretive efforts. The transitory nature of CO contributory parameters such as meteorology and traffic dynamics may induce "anomalous" short-term conditions to which short duration studies of this sort can be oversensitive.

By way of illustrating this last point, the preliminary indication by the National Weather Service is that during the study interval, the seasonal stability that typically characterizes Spokane's winter meteorology was somewhat less severe and persistent than usual, which would tend to reduce CO levels other factors being equal. Additionally, retail sales were reportedly off in the central business district during the holiday season, which would imply some reduction in the typical traffic burden, thereby effecting a depression of CO levels, other factors being equal.

Given the combined impact these somewhat anomalous meteorological and economic situations exert in the suppression of CO levels, data generated by the study should probably be regarded as conservative, or underpredicting in nature.

Finally, routine activities such as building construction and street maintenance introduce relatively short-term perturbations to traffic patterns and flow which may either suppress or exacerbate CO levels. These situations occurred at several locations throughout the CBD and were logged when observed. The ongoing incidence of these activities at various locations within the CBD should be considered "normal".

These considerations are not mentioned in order to devalue the study results in any way, but only to frame them in their proper context for use in making long-term inferences. This serves to underscore the necessity of long-term monitoring in strategy formulation and the tracking of standards attainment.

SUMMARY OF RESULTS

In 1980, a 20-day study of carbon monoxide levels at sixteen ambient sampling sites was conducted in Spokane's CBD during November and December, the "season" when high and persistent concentrations of CO historically occur. The study was directed towards collecting data relative to the magnitude and spatial distribution of CO concentrations for comparison with data retrieved from the permanent monitoring sites.

Following the completion of an analysis* aimed at screening areas for "hot-spot" potential to aid in the design of the sampling network, EPA engaged a contractor** to conduct the field portion of the study. On each weekday (except Thanksgiving day), two sets of 4-hour integrated bag samples representing the 10:00 a.m. to 2:00 p.m. (AM sample) and the 2:00 p.m. to 6:00 p.m. (PM sample) intervals were collected from the 16 sampling sites (see Figure 2 and Table 1). The AM and PM bag samples were in turn analyzed via the NDIR (non-dispersive infrared) method, and the resultant concentrations averaged to yield an 8-hour value, permitting comparison with the 8-hour standard of 9.0 ppm for CO.

Data are summarized in bar charts of the measurement distribution for each site and each day of the study period, and in histogram-maps exhibiting the spatial distribution of CO. Results from the study sites were compared in several ways with data from the state sites, available meteorological data, and with each other.

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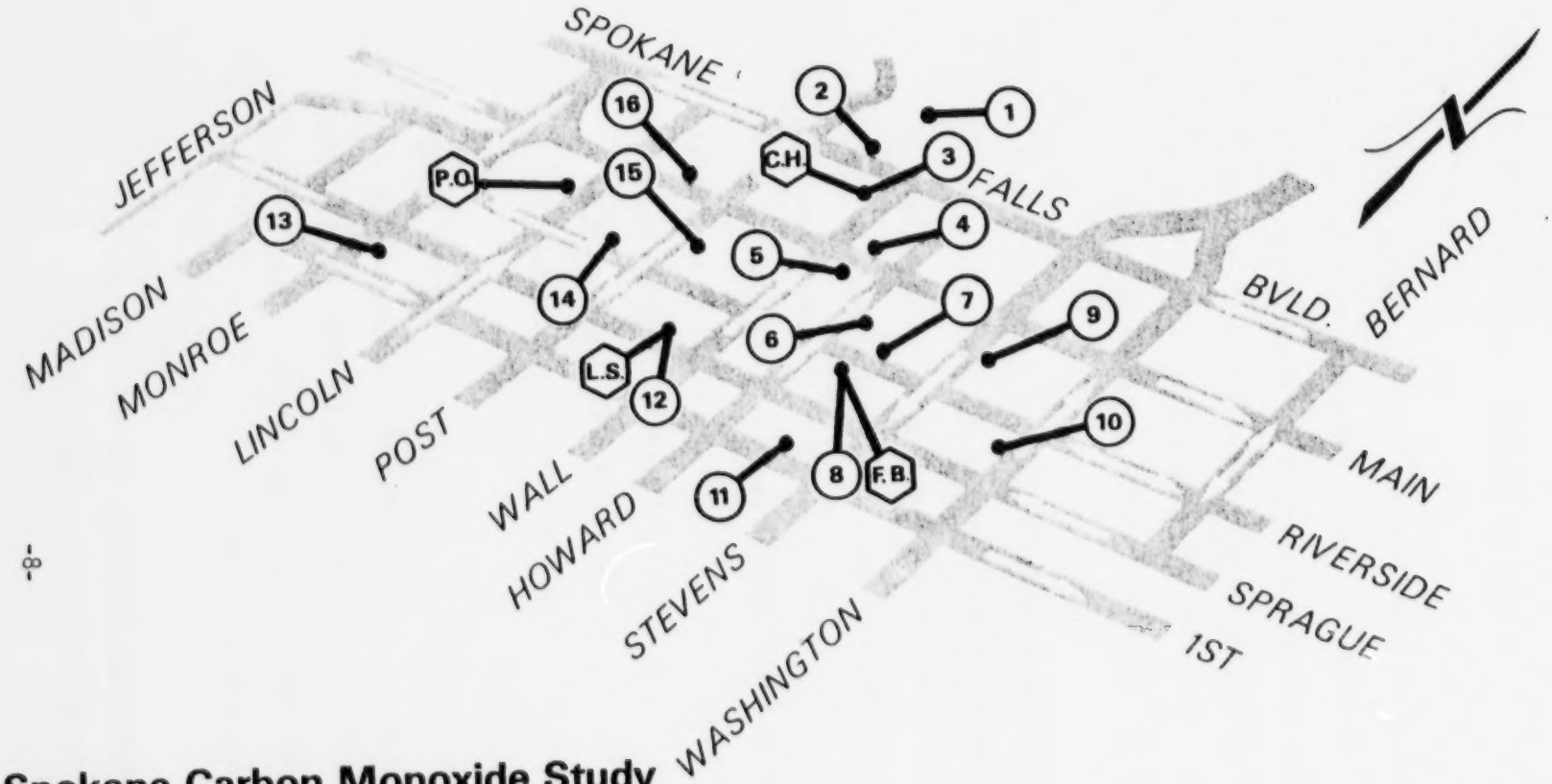
*EPA's Carbon Monoxide Hot-Spot Guidelines, EPA-450/3-78-035.

** Alsid, Snowden and Associates; Bellevue, Washington.



Spokane Carbon Monoxide Study
Location of EPA Sampling Sites
11/21/80 to 12/19/80

State Site

EPA Site

P.O. - POST OFFICE
C.H. - COURT HOUSE
L.S. - LIQUOR STORE
F.B. - FERNWELL BDLG.

Figure 2

TABLE 1

SPOKANE CO STUDY--NOV. 21 TO DEC. 19, 1980
SAMPLING SITE LOCATION

EPA STUDY SITES

SITE NO.	PRIMARY STREET	CROSS STREET	SIDE OF STREET
1	SPOKANE FALLS BLVD.	W/O WALL	N
2	SPOKANE FALLS BLVD.	W/O WALL	N
3	WALL	S/O SPOKANE FALLS BLVD.	W
4	MAIN	W/O HOWARD	N
5	MAIN	W/O HOWARD	S
6	HOWARD	S/O MAIN	E
7	RIVERSIDE	W/O STEVENS	N
8	RIVERSIDE	W/O STEVENS	S
9	STEVENS	S/O MAIN	E
10	WASHINGTON	S/O RIVERSIDE	W
11	FIRST	W/O STEVENS	N
12	SPRAGUE	W/O WALL	N
13	MONROE	S/O SPRAGUE	E
14	RIVERSIDE	W/O POST	N
15	POST	S/O MAIN	E
16	MAIN	W/O POST	N
STATE PERMANENT MONITORING SITES			
Post Office (PO)	LINCOLN	S/O MAIN	W
(Station No.: 3278013A)			
Liquor Store (LS)	SPRAGUE	W/O WALL	N
(SAROAD No.: 49 2040 027 F01)			
Fernwell Bldg. (FB)	RIVERSIDE	W/O STEVENS	S
(Station No.: 3278033A)			
City Hall (CH)	WALL	S/O SPOKANE FALLS BLVD.	W
(Station No.: 3278001A)			

The study indicated that the carbon monoxide problem is not restricted to the immediate vicinity of the permanent sites, but pervades the CBD. This is evidenced by the fact that 12 of the 16 study sites, or 75%, exhibited at least one "exceedance"* of the 8-hour NAAQS for CO. Comparisons of the 8-hour averages at the study sites and the permanent monitors revealed that the highest 8-hour average at a study site (13.7 ppm) was about the same as that measured at any of the permanent monitors (13.0 ppm) for the corresponding 10:00 a.m. to 6:00 p.m. interval.

Of the permanent monitors, the one located at the Post Office on Lincoln Street south of Main Avenue, had the maximum 8-hour average, the 2nd-highest 8-hour average, the highest average of 8-hour values over the entire study interval, and the greatest frequency of exceedances. A study site on Riverside Avenue experienced a slightly higher maximum 8-hour concentration, though one less exceedance of the standard. However, two other study sites equalled the Post Office monitor in number of exceedance values. Significantly, the Post Office permanent monitor did not exhibit an 8-hour exceedance on 3 of the 6 days when at least one site in the study network did so and for which comparative data was available. In fact, when the permanent sites are considered in aggregate, they did not produce an exceedance value on 2 of the 6 days when at least one study site did so and where comparative data were available. Conversely, at least one site in the study network, excluding those collocated with the permanent monitors, exhibited an exceedance when one was reported from among the permanent monitors.

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*An exceedance is defined as any 8-hour average concentration of CO greater than the 9.0 ppm standard.

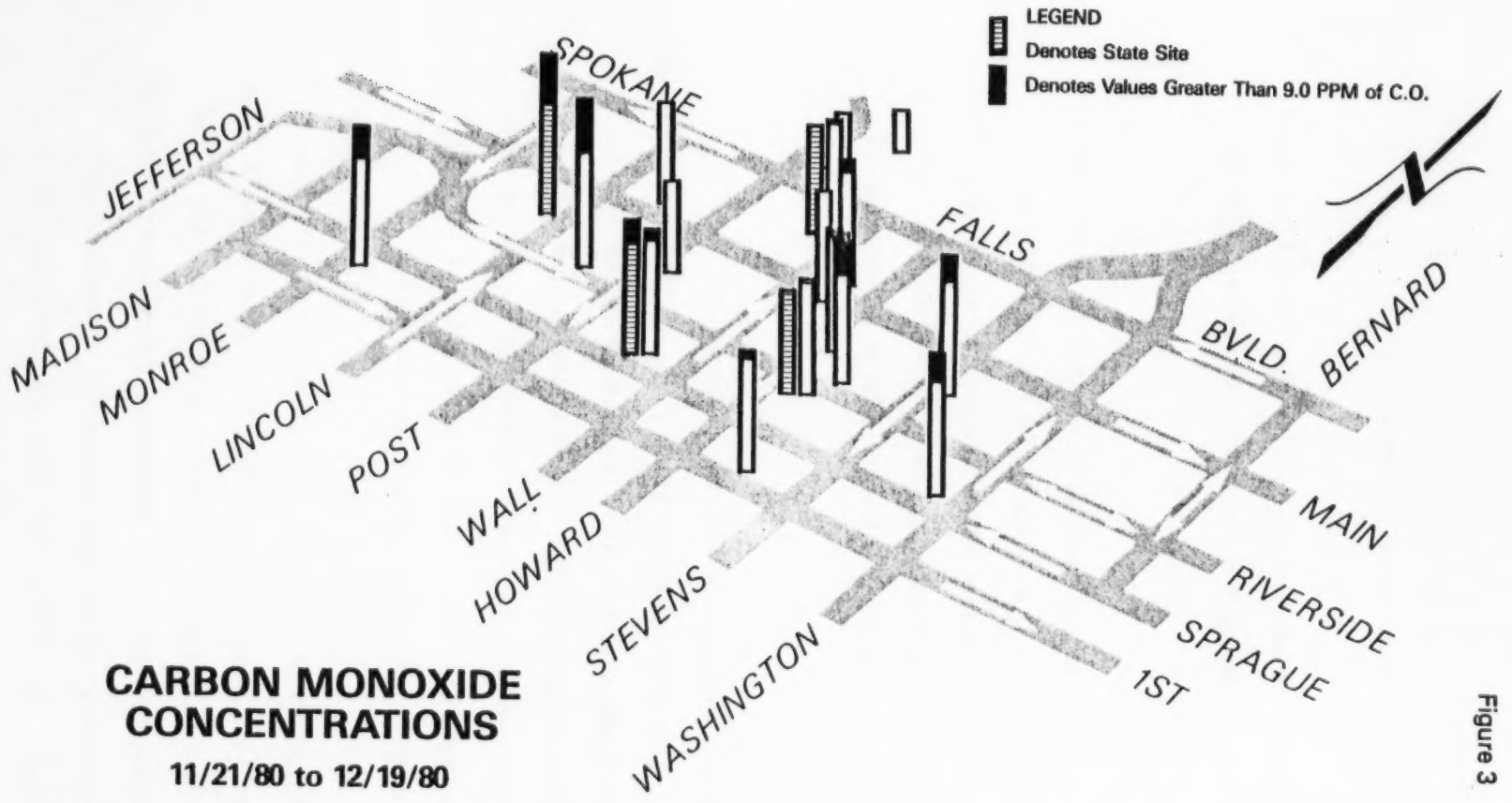
CONCLUSIONS AND RECOMMENDATIONS

The primary conclusions drawn from the results of a CO sampling study conducted in Spokane on weekdays of November and December, 1980 during the 10:00 a.m. to 6:00 p.m. interval are:

1. The severity of carbon monoxide concentrations in the CBD as measured by the maximum 8-hour 10:00 a.m. to 6:00 p.m. concentrations, compared without respect to day of occurrence, was adequately represented by the permanent monitor located at the Post Office on Lincoln Street south of Main Avenue (see Figures 3 and 4).

   - During the study period, the maximum 8-hour CO concentration among all study sites was 13.7 ppm, occurring on December 12th at site 14 on Riverside west of Post. This was essentially the same as the maximum value experienced at the permanent monitors during the study period (13.0 ppm, also on December 12th, at the Post Office monitor, located on Lincoln south of Main).

   - About 38% of the study sites (5 of the 13 sites not collocated with permanent monitors) experienced at least one 8-hour average concentration within 2.0 ppm of the highest 8-hour value reported by the permanent monitors, demonstrating the spatial severity of concentrations in the study area. (Note that these are comparisons of the maximums during the 20-day study period and did not necessarily occur on the same day.)



CARBON MONOXIDE CONCENTRATIONS

11/21/80 to 12/19/80

SPOKANE CENTRAL BUSINESS DISTRICT

MAXIMUM 8-HOUR[1] VALUES FOR ENTIRE SAMPLING INTERVAL

[1]10 AM TO 6 PM

Scale in PPM C.O. 10 5 0

Figure 3

Spokane Carbon Monoxide
November 21 to December 19, 1980
(Weekdays Only)

Characteristics of Weekday Carbon Monoxide Average Concentrations for an Eight-Hour Period (10:00 a.m. to 6:00 p.m.) at Each Site.

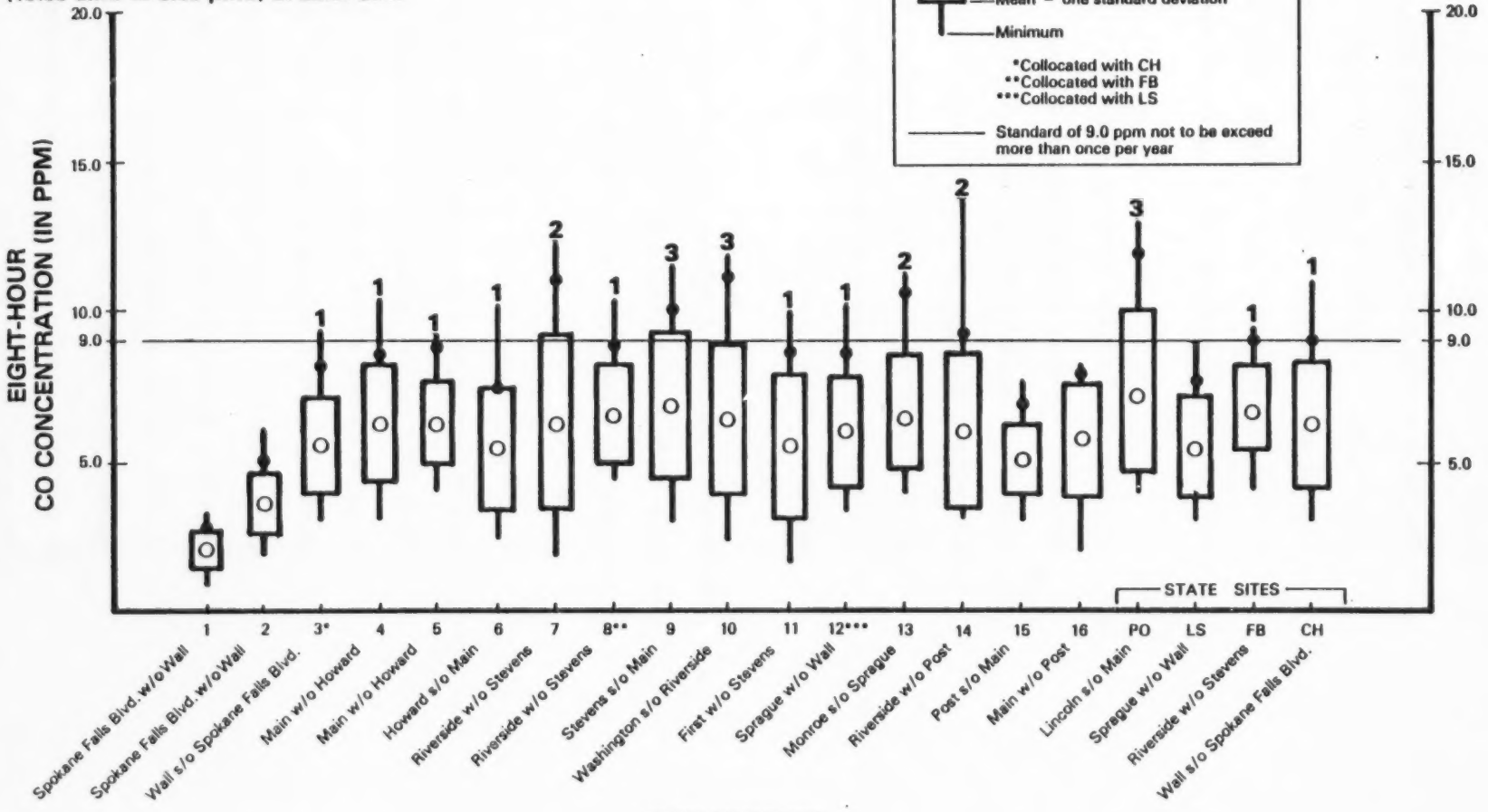


Figure 4

- The maximum 8-hour averages at each of these five study sites (sites 7, 9, 10, 13, and 14) exceeded the maximum reading of 11.0 ppm at the Liquor Store monitor (located on Sprague Avenue west of Wall Street), which was the next highest maximum reading from a permanent monitor.

- About 69% or 9 of the 13 study sites not collocated with permanent monitors produced 8-hour maximum values which equalled or exceeded the maximum 8-hour concentrations of 9 ppm and 9.4 ppm reported from the City Hall (Wall Street south of Spokane Falls Blvd.) and Fernwell Building (Riverside Avenue west of Stevens Street) permanent monitors, respectively.

2. The permanent monitoring network did not necessarily represent the daily 10:00 a.m. to 6:00 p.m. maximum CO concentration within the study area for this 20-day period (see Figure 5).

   - On 61% of the days (11 of the 18 days for which comparable data is available), the highest 8-hour value measured at a study site not collocated with a permanent monitor, clearly exceeded values at the permanent monitors, by an average of about 2 ppm and a maximum of about 3 ppm. The maximum daily value from among the permanent monitors clearly exceeded that value from the study sites on 11% (2 of 18) of the days, by an average of about 1 ppm. The daily maximum values from both permanent monitors and study sites were roughly equal (uncertain because of state rounding procedures) on 28% (5 of 18) of the days.

Spokane Carbon Monoxide
November 21 to December 19, 1980

Characteristics by Day of the Composite Range of Carbon Monoxide Concentrations for all Sites During an Eight-Hour Period (10:00 a.m. to 6:00 p.m.).

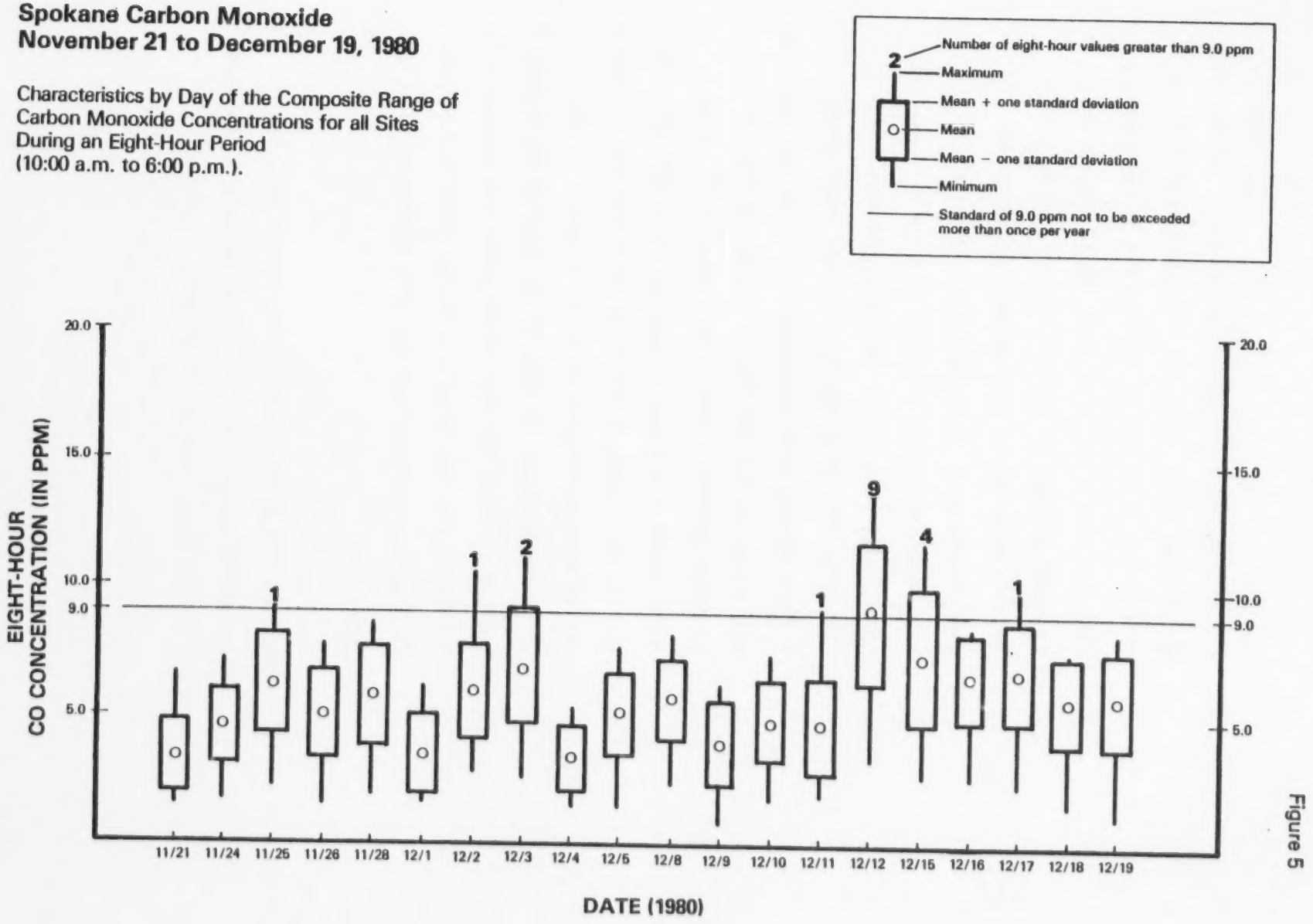


Figure 5

- The maximum 8-hour average of the day did not always occur at the same sites. Excluding from consideration those study sites (3, 8, and 12) collocated with permanent monitors, study sites 4, 5, 7, 9, 10, 13, and 14 and permanent monitors at the Post Office, City Hall and Fernwell Building all were maximum, or shared that distinction, on at least one day during the study, for which comparable state and study data are available (18 days). Site 9 was highest on 22% of the days. Site 10 was highest on only 6% of the days, but was equal to the highest reading on an additional 17% of the days, each time with either or both the Post Office and Fernwell Building permanent monitors. Site 5 was highest on 17% of days. Sites 13 and 7 were each highest on 11% of the days, and equally the highest an additional 6% of the days. Sites 4 and 14 were each highest on 6% of the days. Of the permanent monitors, the Post Office equalled the highest reading on 22% of the days, three times with study site 10, and twice with the Fernwell Building. Finally, the City Hall permanent monitor had the daily maximum on 6% of the days.

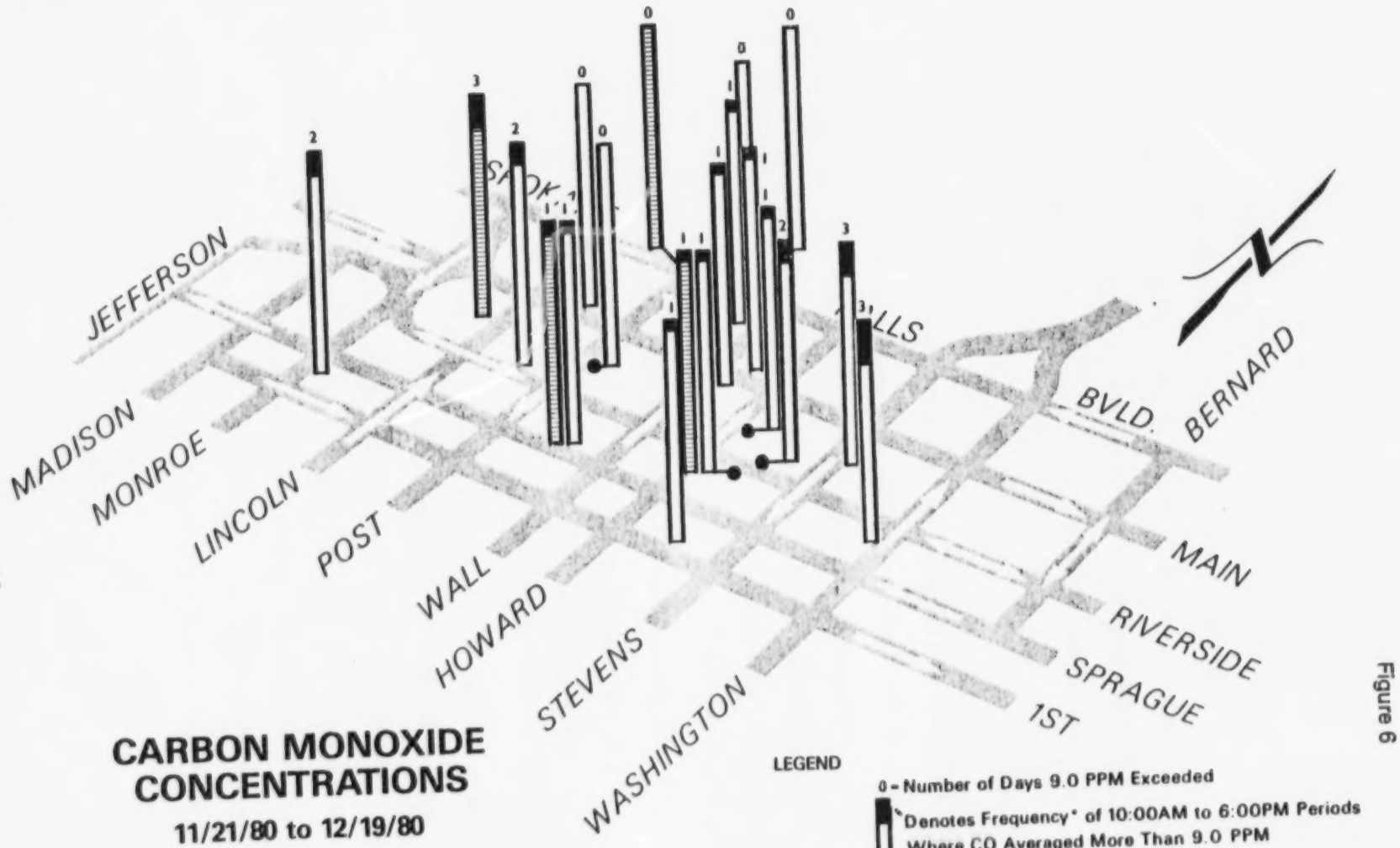
3. On occasion, the permanent monitoring network exhibited sub-exceedance values when study sites elsewhere in the study area reported exceedances of the standard.

- The 8-hour standard was exceeded at one or more of the study sites on 35% (7 of 20) of the study days. Exceedances at one or more of the permanent monitors occurred on 20% (4 of 20) of the sampled days. Two days of state data were invalidated due to system malfunctions, during one of which a study site (13) showed an exceedance (10.6 ppm).

- When considered on an individual site basis, the Post Office permanent monitor was representative of the frequency of exceedances within the study area, at 17% (3 of 18 days). This figure was equalled at study sites 9 and 10 (see Figure 6).

- The frequency of exceedances at the permanent monitors ranged from 0% at City Hall to 17% of the sampled days at the Post Office.

4. Using the results of linear regression analyses, the permanent monitoring network was effective in characterizing CO concentrations at all study site locations. Two types of linear regressions were performed: simple paired linear regressions, and multiple linear regressions (MLR) where data from three permanent monitors were input as "independent" predictors of a "dependant" study site value.



CARBON MONOXIDE CONCENTRATIONS

11/21/80 to 12/19/80

SPOKANE CENTRAL BUSINESS DISTRICT

FREQUENCY[1] OF 8-HOUR[2] VALUES GREATER THAN 9.0 PPM

[2] 10 AM TO 6 PM

LEGEND

0 - Number of Days 9.0 PPM Exceeded

* Denotes Frequency* of 10:00AM to 6:00PM Periods Where CO Averaged More Than 9.0 PPM

- State Site

*ROUNDED TO NEAREST 5%

[1] LESS THAN 20 SUCCESSFUL SAMPLING DAYS OCCURED AT SOME SITES
(FIXED BAR HEIGHT REPRESENTS 100% OF DAYS IN WHICH SUCCESSFUL SAMPLING OCCURED)

Figure 6

- The highest coefficient of correlation resulting from the regression analyses for each study site was always greater than 85%. Excluding from consideration those study sites collocated with permanent monitors, 9 of the 13 remaining study sites had regression correlation coefficients of 94% or better.

- Considering individual permanent monitors, data from the Liquor Store monitor exhibited the most extensive correlation with data from the study sites. It showed a correlation coefficient of 80% or better for 11 of the 16 study sites. The Post Office monitor had correlation coefficients of 80% or more for 5 of the 16 study sites. The City Hall and Fernwell Building had no correlation coefficients greater than 80%, excluding their collocated study sites.

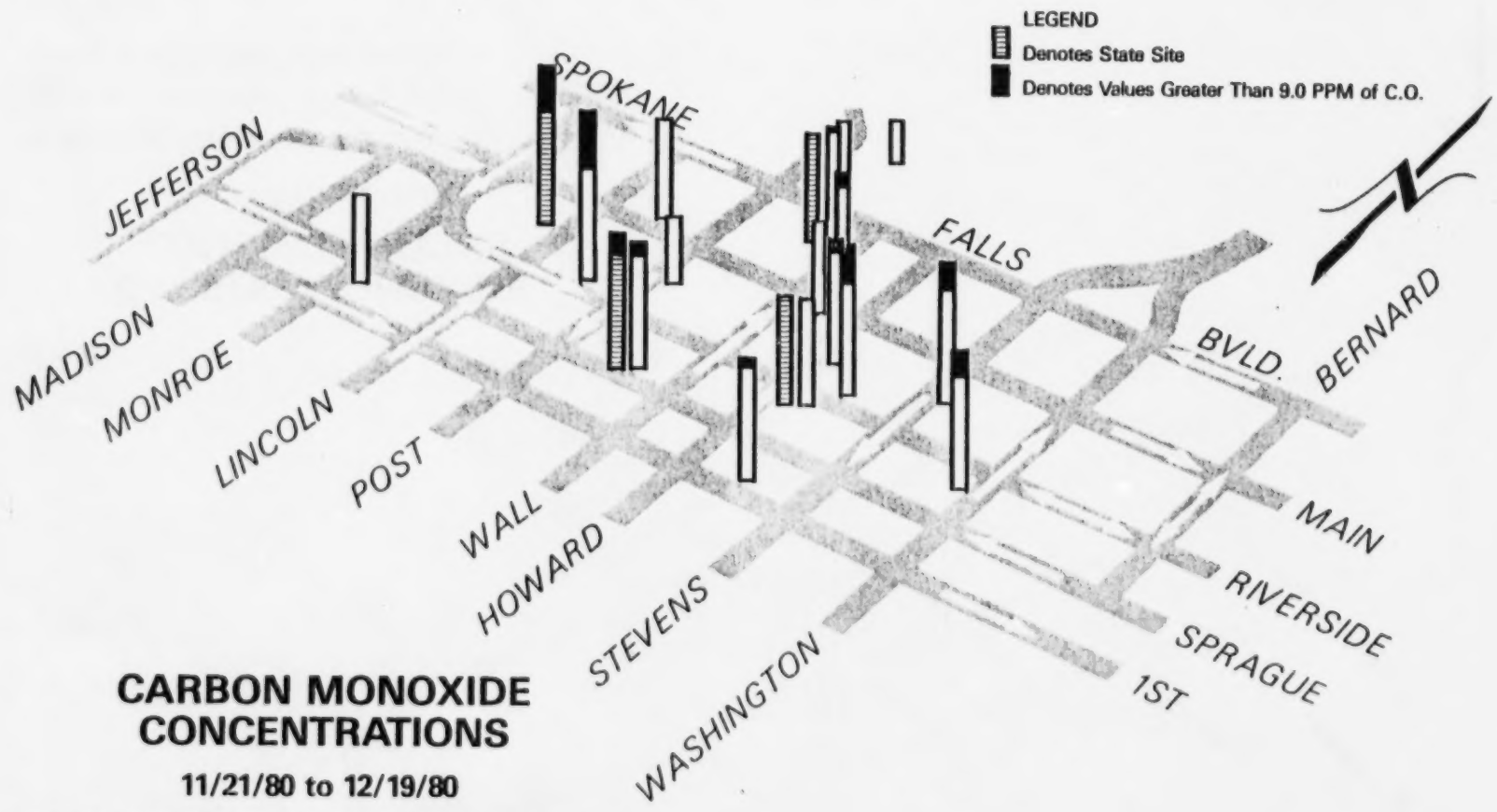
- When considering the four possible combinations of three permanent monitors in the multiple linear analysis, three combinations, (1 - Post Office, Liquor Store, City Hall, 2 - Post Office, Liquor Store, Fernwell Bldg., 3 - Liquor Store, Fernwell Bldg., City Hall), had or shared the highest correlation coefficient at 9 or 10 of the 13 study sites (the three study sites collocated with the permanent monitors were excluded from the comparison). Finally, the Post Office, City Hall, and Fernwell Building combination had the highest correlation coefficient at just 1 of 13 study sites.

5. Carbon monoxide concentrations were lower at some locations in the CBD than others for corresponding intervals (see Figures 7 and 8).

- For 25% of the study sites (sites 1, 2, 15, and 16) no 8-hour values exceeding the 9.0 ppm standard were reported during the 20-day study.

- Relatively low concentrations were observed at sites 1 and 2, which were located in areas offering good ventilation. For these sites the averages of all eight-hour values were 2.0 and 3.5 ppm respectively. Study site 1, located about 75 meters from the nearest street, had the daily minimum 8-hour value on all 20 sampling days, and probably approximates background concentrations of CO. Eight-hour concentrations at site 1 ranged from .8 to 3.4 ppm during the study interval.

- On occasion, sites on one side of the street showed high, even exceedance values, when sites directly across the street reported lower, sub-exceedance values. This occurred several times at both sets of "cross-street pairs": sites 4 and 5 on Main west of Howard and sites 7 and 8, on Riverside west of Stevens. The former pair had a near random linear correlation coefficient of 4%, while the latter pair had one of 56%.



CARBON MONOXIDE CONCENTRATIONS

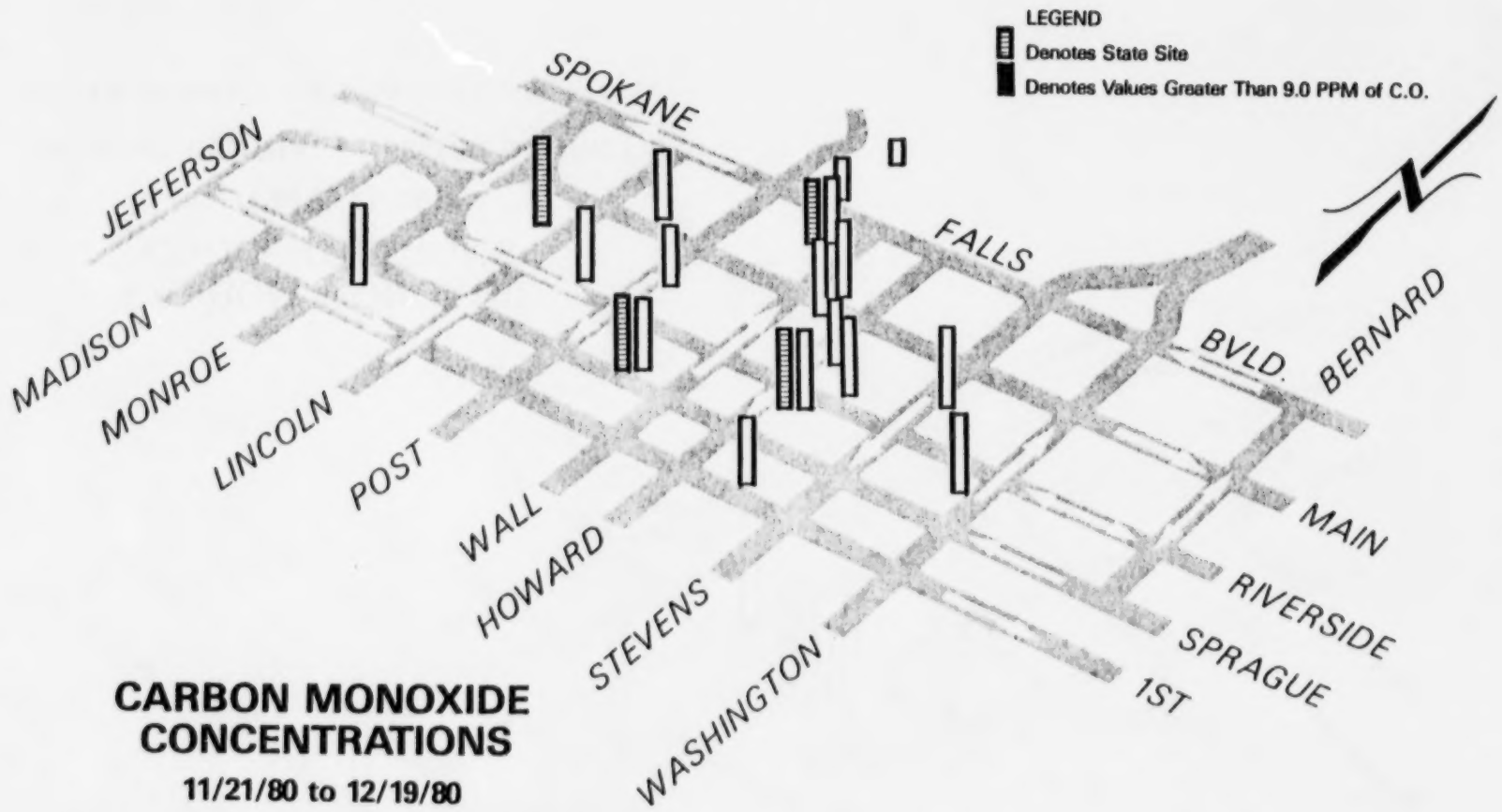
11/21/80 to 12/19/80

SPOKANE CENTRAL BUSINESS DISTRICT

DAY[1] OF HIGHEST AVERAGE OVER ALL SITES

[1]12/12/80 - 10 AM TO 6 PM

Figure 7



CARBON MONOXIDE CONCENTRATIONS

11/21/80 to 12/19/80

SPOKANE CENTRAL BUSINESS DISTRICT

AVERAGE OF EACH SITE'S 8-HOUR[1] VALUES FOR ENTIRE SAMPLING INTERVAL

[1]10 AM TO 6 PM

Figure 8

It is recommended that:

1. The carbon monoxide situation in Spokane be considered an area-wide problem in the study portion of the CBD, as opposed to a few isolated "hot spots". While examination of the "cross-street pair" and "background" data analyses confirms that CO levels are primarily expressions of highly localized factors, it should be recognized that the CBD offers an extensive array of sites which fit the "hot-spot" scenario.

2. Concentrations at the permanent monitoring network above 9.0 ppm be considered as indicative of concentrations equally high or higher elsewhere in the study area at the same time. However, should the permanent monitors measure concentrations under the 9.0 ppm (in the 5 to 9 ppm range) standard on a particular day, it should not be construed as assurance that air quality standards are being met throughout the study area on the same day.

3. Given the current mix of non-meteorological parameters within the study area, the Post Office permanent monitor be considered as a candidate site to represent peak CO levels in downtown Spokane for routine monitoring. However, the Liquor Store monitor should be utilized as the single, most representative site from which to infer CO levels at other sites within the study area, as calculated from regression results.

4. Concentrations at the permanent monitoring network be input to the appropriate multiple linear regression formula and the output used to characterize concentrations at locations other than at the permanent monitors.

5. Planning for future studies to aid development and/or revision of control strategies to attain the NAAQS should consider the possible utility of ancillary data on traffic and meteorological parameters to aid data interpretation.